Patent Application Serial No. 10/813,789
Filed March 23, 2004

DECLARATION OF JOHN CONLEY Jr.

I, John Conley Jr., hereby declare as follows:

1. My residence address is 4652 NW Walden St., Camas, WA, 98607

2. Since 2001, I have been employed by Sharp Laboratories of America (SLA), Inc., 5700 N.W. Pacific Rim Boulevard, Camas, Washington 98607. My title is Sr. Research Scientist / Leader. Novel Materials and Devices Group. My responsibilities include research and management of research projects.

3. I am a co-inventor of Patent Application Serial No. 10/813,789. With the full knowledge of my co-inventors Yoshi Ono and Wei Gao, I hereby state and declare unequivocally that I, along with my co-inventors, invented the device recited in claims 1-20 prior to November 17, 2003.

4. Attachment D is a true copy of the SLA patent disclosure document filed with the SLA Patent Department. I affirm that the patent disclosure document was written, signed, and witnessed before November 17, 2003. The disclosure shows the concept of a microlens structure formed by patterning a hard mask formed over a transparent film, and etching the hard mask and transparent film to form a lens shape.

5. Attachment E is a true copy of a monthly report written by co-inventor Wei Gao to co-inventor Yoshi Ono. The figures and descriptions in the report are very similar to both the disclosure and patent application. For example, Figs. 1-4 in the report are almost identical to the figures appearing on pages 7 and 8 of the disclosure, and Figs. 3-6 in the

application. Fig. 7 in the monthly report, and its accompanying explanation, show and describe the formation of a microlens, and are proof that the invention recited in claims 1-20 was reduced to practice. This monthly report was filed prior to November 17, 2003.

6. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful, false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United State Code and that such willful, false statements may jeopardize the validity of the application or patent issuing thereon.

5/11/06
Date

John Conley Jr.

SHARP Laboratories of America, Inc.
5750 NW Pacific Rim Boulevard
Camas, Washington 98607

OIPE MAY 19 2006 IAP85 PATENT & TRADEMARK OFFICE

SLA Confidential

SLA Docket No. 0837

INVENTION DISCLOSURE FORM

Q1. Has a provisional patent application or related patent application been filed previously for this case or a closely related case? If so, indicate relevant SLA numbers.

SLA_____	Relation:
SLA_____	Relation:
SLA_____	Relation:
SLA_____	Relation:

Q2. Descriptive title of invention:

A method of making microlens arrays for photosensitive devices, and LCD displays

Q3. Inventor(s):

Inventor 1

Full Legal Name:	Wei		Gao		
	First	Middle	Last		
Address:	2402 SE 180th CT	Vancouver	WA	98683	Clark
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	Home	Company			

Inventor 2

Full Legal Name:	Yoshi		Ono		
	First	Middle	Last		
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	Street	City	State	Zip	County
Citizenship:					
Telephone:	(360) 834 7060	(360) 834 8582			
	Home	Company			

Inventor Signature — Date [redacted]

Inventor Signature — Date [redacted] — T. Li Witness initials (include date if witnessed on date different from above)

Inventor Signature — Date [redacted] — Witness initials (include date if witnessed on date different from above)

SLA Docket No. 0837

Inventor 3						
Full Legal Name:	John (First)	F. (Middle)	Conley, Jr. (Last)			
Address:	4652 NW Walden (Street)	Camas (City)	WA (State)	98607 (Zip)	USA (County)
Citizenship:						
Telephone:	(360) 834 1985 (Home)	(360) 834 8668 (Company)				

Q4. Witnesses (acquire signatures AFTER supervisor signs Q5):

Witnessed and understood by:					
Full Legal Name:	TING KAI (First)	(Middle)	LI (Last)		
Address:	18701 SE 23rd (Street)	Vancouver (City)	WA (State)	98683 (Zip)	(County)
Date:	[redacted]				
Signature:	[signature]	Initials	T. Li		

Witnessed and understood by:					
Full Legal Name:	Wei (First)	(Middle)	Pan (Last)		
Address:	17311 SE 23rd Way (Street)	Vancouver (City)	WA (State)	98683 (Zip)	Clark (County)
Date:	[redacted]				
Signature:	[signature]	Initials	W.P.		

Inventor Signature	Date [redacted]	
Inventor Signature	Date [redacted]	T Li — Witness initials (include date if witnessed on date different from above)
Inventor Signature	Date [redacted]	Witness initials (include date if witnessed on date different from above)

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Q5. Supervisor's Acknowledgement:

"I believe this disclosure is novel and complete and should be submitted to the Patent Review Committee."

Supervisor's Signature: Shengteng Hsu
Date: [redacted]

Supporting Group: ☐ CRDG ☐ AVSG ☐ CSG ☐ ISG ☐ DSG
☑ ICG ☐ LCDG ☐ Other: ______

Inventors' Department: ☐ DAVS ☐ MMC ☐ DI ☐ IST ☐ IC ☐ LCD

Q6. Project & supervisor:

Supervisor's Name: Sheng Teng Victor Hsu
Supervisor's Title: Director, IC Process Technology
Project Number/Name:

Q7. Conception of the invention:

Date Conceived: [redacted]
Date of first Written Description: [redacted]
Notebook & Page No. or File Archive:
Date first explained to others (whom?):
Planned Application for the Invention: Solid state image sensors and detectors

Q8. Construction & test of first prototype embodying the invention.

Date First Prototype Completed:
Part Number/Product Description:
Date of First Successful Test:
Successful Operation Witnessed By:

Inventor Signature	Date [redacted]	
Inventor Signature	Date [redacted]	T. Li Witness initials (include date if witnessed on date different from above)
Inventor Signature	Date [redacted]	Witness initials (include date if witnessed on date different from above)

Q9. Public disclosure of invention (A patent application SHOULD be filed prior to any public disclosure. If there has already been a public disclosure, please contact the Patent Department).

Date of First Public Disclosure: ______________________

Setting (Conference/Journal Name): ______________________

Title of Paper or Presentation: ______________________

Type of Disclosure (Written/Verbal): ______________________

Does Data Sheet or Application Note Disclose the Invention (when)? ____________

Q10. What problem does the invention solve and how is this problem currently solved (Summarize the current state of the art--do not include patent search results here.)?

As the demand for cheaper and more powerful image sensors increases so does the need to decrease pixel size and improve resolution. This, however, reduces the photo-active area and its sensitivity. This sensitivity loss can be countered by using a microlens placed above each pixel. If the position and shape of the lens is fabricated correctly the lens will divert light rays that would normally impinge on areas between pixels and concentrate it onto sensor, thereby increasing the electrical signal. Prior art employs a photo resist reflow method to form the shape of the lens and dry etch to transfer the shape to the lens material (normally high refractive index resin) underneath. The biggest limitation of this method is the space between lens has to be at least 0.3μm in order to prevent the photo resist islands from contacting each other during the reflow process. Another prior art uses an etching method to control the side-wall angle so that the space between lens can be reduced or eventually join together to increase the collection efficiency and fill factor. However, controlling the side-wall slope complicates the process. Since the etching process is very equipment and material dependent, the technology is difficult to transfer. In the case when the microlens array is not a square shape, the reflow method has difficulties to focus the light to one point. Approaches were proposed but process complication is inevitable. This invention is to provided a method to fabricate microlens with simplicity and easy to control on lens shape.

Q11. For the benefit of the Patent Committee or supervisor, state a summary of the invention including primary unique aspects of the invention (Not to exceed 3 pages).

This invention provides a method to fabricate an array of micro-lenses. In most prior art cases, the shape of the lens is made to protrude above the surface of the top plane to form the convex lens shapes. In this case, the convex lens is shaped into the plane with a novel etch technique. The mold for the lens is formed by one dry etch step and one wet etch step. The high refractive index lens material is deposited after the mold

Inventor Signature	Date [redacted]	
Inventor Signature	Date [redacted]	T. L. Witness initials (include date if witnessed on date different from above)
Inventor Signature	Date [redacted]	Witness initials (include date if witnessed on date different from above)

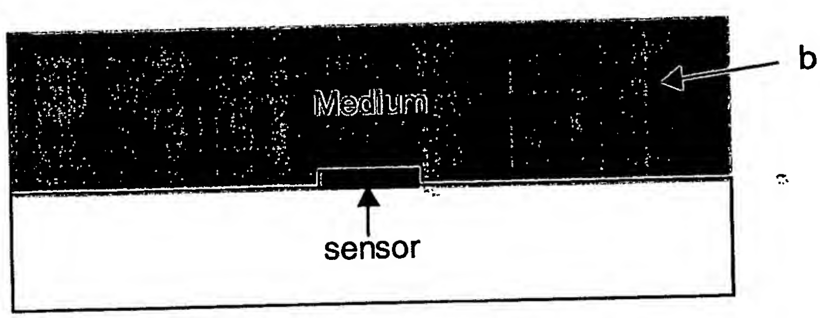
formation. The shape of the mold in this invention is controlled by the mask material, the underlying film that will generate the shape of the mold, the etch selectivity duration of the etch. The process details could be calculated from the dimension of the desired lens and the targeted focal length. The collection efficiency could be maximized by increasing the fill factor value to as high as 100%. For the photosensitive device or lens array that is not in a square shape, this method could focus the light to a single round spot or a different shape of spot as required in the design. This method could not only be used on photosensitive devices, it could also be used on liquid crystal display panels.

Q12. Would one skilled in the art of the invention need to refer to any published documents, in addition to your disclosure, in order to make and use the invention? If so, list references and summarize relevant material.

Q13. Provide a detailed description of the invention.

In the case of liquid crystal display device, the lenses are made on a glass substrate. On CCD and other imaging devices, the lenses are made after devices are fabricated. The following description uses a single photosensitive pixel as an example.

Once the photodetector are fabricated, the medium (layer ***b***) that the mold will be made on is deposited as is shown in the following figure. Since the light is going to be transmitted through this medium, it should be transparent, and in order to bend the light effectively from the interface with the lens, it should have a low refractive index value. However, this layer can be any state-of-the-art material deposited by any state-of-the-art method.



In the next step, a hard mask layer ***a*** is deposited. This material should have an etch rate faster than the medium ***b*** layer by a required factor ***s***. The thickness of this hard mask layer ***a*** depends soley on the thickness of the microlens. The material for this

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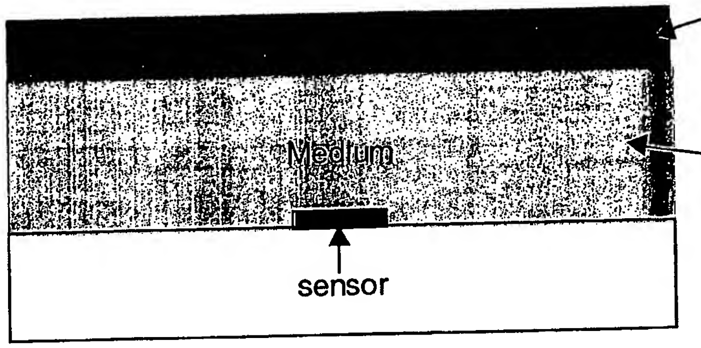
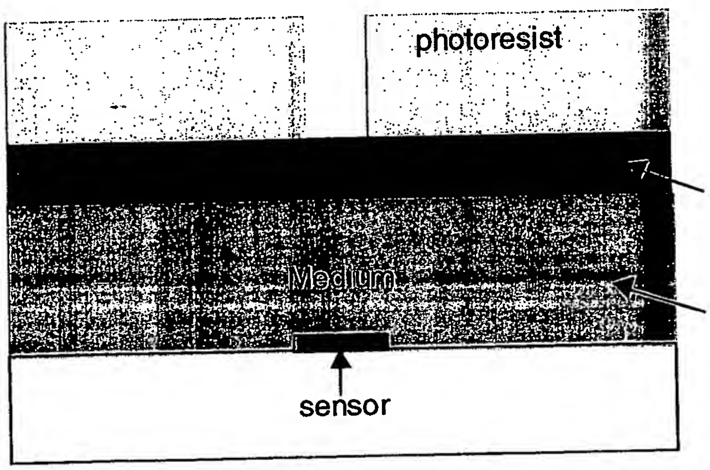
layer could be any state-of-the-art material, it could also be as simple as photo resist. In the case of photo resist, the next process step is not needed.



The next step is to coat photo resist and pattern an opening much smaller than the size of the lens through standard photo-lithography.



Then the hard mask layer is dry etched stopping at the medium layer ***b***. The photo-resist is removed. The shape of the opening on the hard mask could be any shape as needed, however, for this example, the opening is a round shape with diameter ***r*** and the hard mask thickness is ***t***

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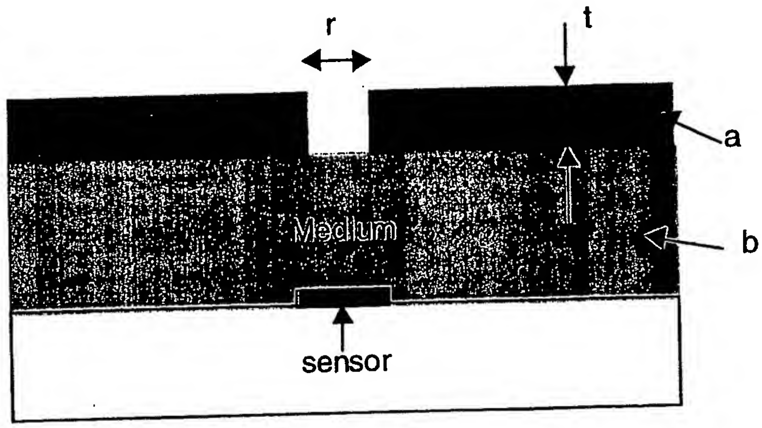
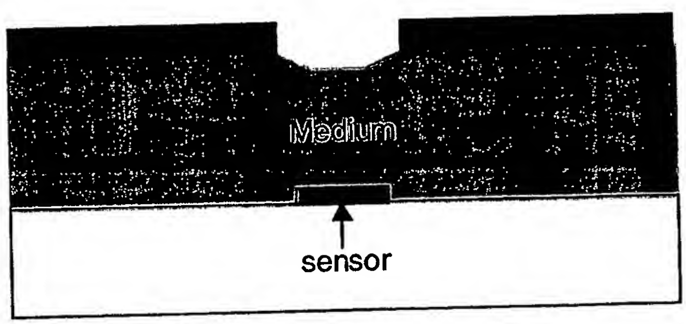
Inventor Signature	Date [redacted]	T. Li Witness Initials (Include date if witnessed on date different from above)
Inventor Signature	Date [redacted]	Witness Initials (Include date if witnessed on date different from above)



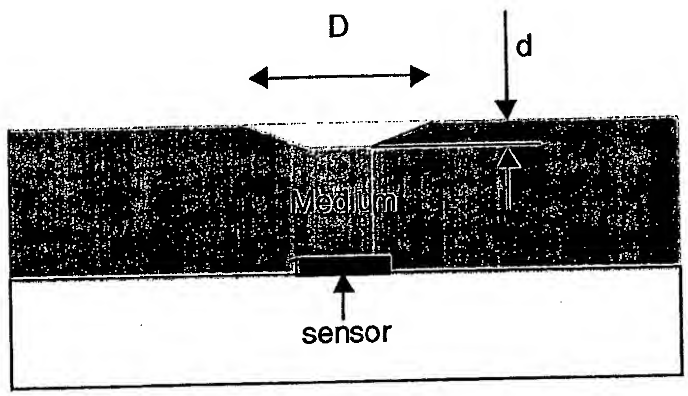
The next step is the wet etch. The etchant is chosen so that it etches both the hard mask ***a*** and the medium material ***b*** with a ratio of ***s*** in favour to the hard mask, i.e. the hard mask ***a*** is etched ***s*** times as fast as the medium material ***b***. The hard mask layer is consumed over time both vertically and laterally. This makes the opening bigger with time so as to form a cone shape mold. The etchant could be any state-of-the-art chemicals as far as it satisfies the selectivity requirement by this method.



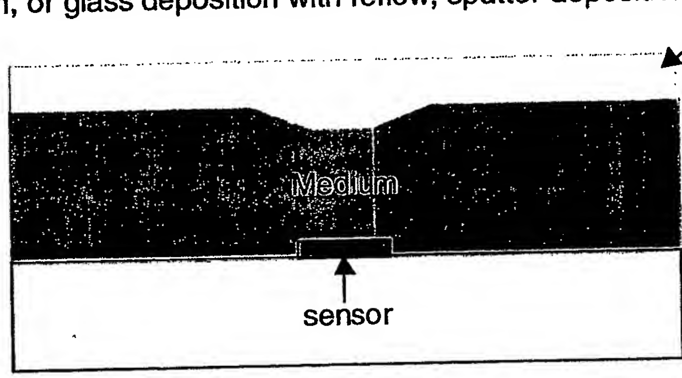
When the hard mask is consumed in its entirety, the etch could be stopped. The thickness of the deposited hard mask layer ***a*** is calculated so that by the end of wet etch, the mold will have the correct dimensions for the microlens. It can be formulated as the following:

lens diameter **D** = 2 x hardmask thickness ***t*** + diameter of dry etch opening ***r***
thickness of the lens **d** = hard mask thickness ***t*** / etch selectivity ***s***

Based on the nature of wet etches, the mold will have rounded corners which is likely to be better for light transmission.



When the mold is formed, the lens material ***c*** with high refrective index value is filled in to the mold. The method of filling could be any state-of-the-art method, e.g. spin-on deposition, or glass deposition with reflow, sputter deposition with CMP, etc.



The lens could be used as is, or could be formed by one extra etching

Inventor Signature	[redacted] Date	
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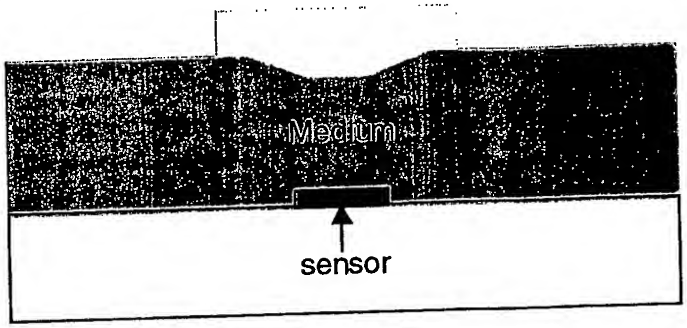
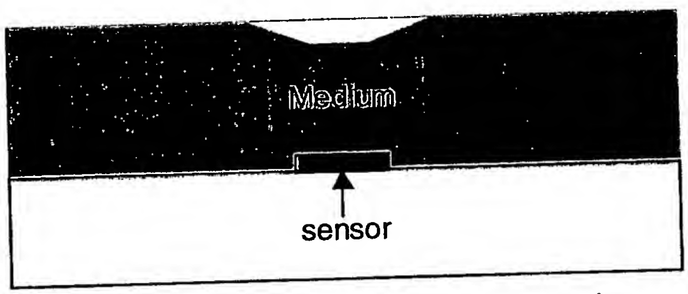
Inventor Signature	[redacted] Date	Witness Initials (include date if witnessed on date different from above)



lens could also be formed by etch back or CMP.



The microlens could be finished by adding anti-reflective-coating as required in design in order to reduce reflection. This layer can be any state-of-the-art material deposited by any state-of-the-art method.

the purpose of this microlens system is to increase the light intensity on the surface of the photo sensor device. Although the shape of the lens is not perfectly spherical or parabolic, the requirement is not to focus to a single point. Rather concentrating the light onto the area of the photo sensor is sufficient. As the following picture demonstrates.

[redacted]

Inventor Signature

Date [redacted]

T. Li

Inventor Signature

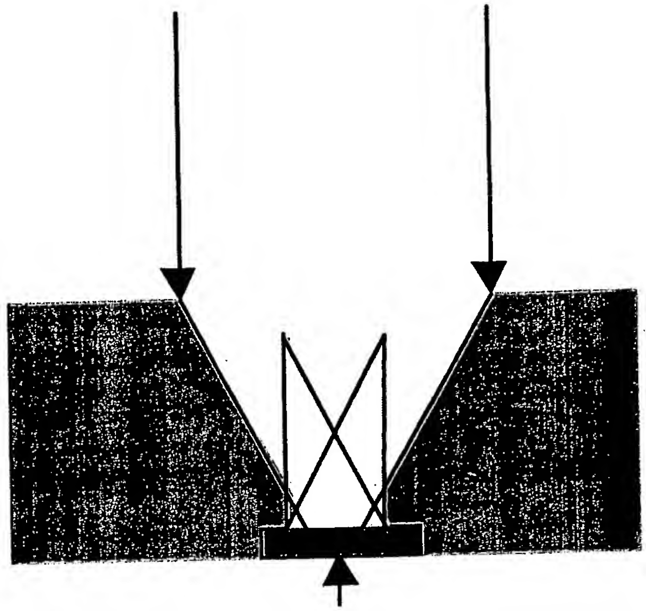
Date

Witness Initials (include date if witnessed on date different from above)

Inventor Signature

Date [redacted]

Witness Initials (include date if witnessed on date different from above)



sensor

By using this method, the lens dimension is determined by the dry opening hardmask thickness and etching selectivity. In such case as when fine tuning of the lens dimension is required, or the etching selectivity is not fully satisfied, a different method of dry etching could be used to provide up to 40% adjustment of the etch selectivity as is shown in the following figure.

By reducing the side wall angle, the etch rate for hard mask could be increased according to the angle. For example, at 60° the lateral etch rate is increased by a factor of $1/\sin 60° = 1.155$ that is around 15% increase. At 45° the increase is 41.4%. Please note that in this case, the overall etching time remains the same, i.e. the lens will have the same thickness ***d*** but bigger diameter ***D***.

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Inventor Signature — Date [redacted]

T. Li
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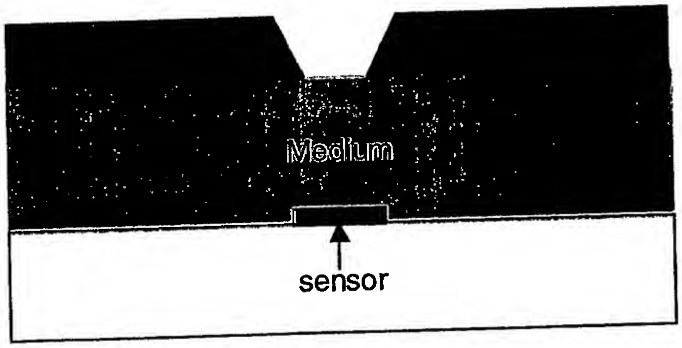
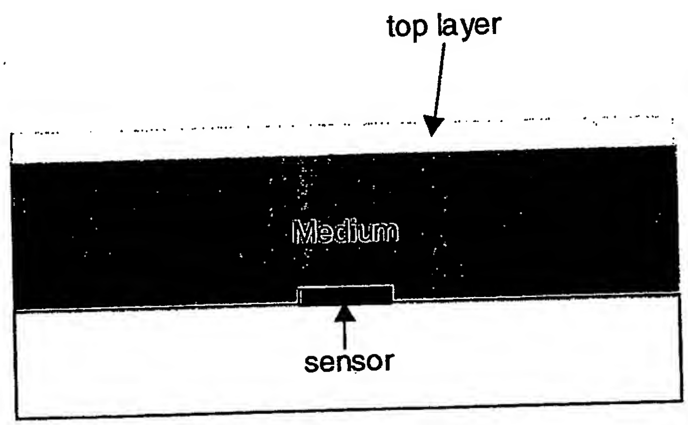
Inventor Signature — Date [redacted]

Witness Initials (include date if witnessed on date different from above)



in the situation that better lens shape is required, the medium layer could have a bilayer structure that provides slight etching rate difference.



As is showing in the following figure, due to the different etching rate, the final shape of the lens is modified to provide better focal point control. This figure shows the result after lens is formed. The bottom part of the medium has slower etch rate than the top part. So that the slope of the lens etched through the bottom part is smaller than the top part which produces near ideal shape of the lens profile.

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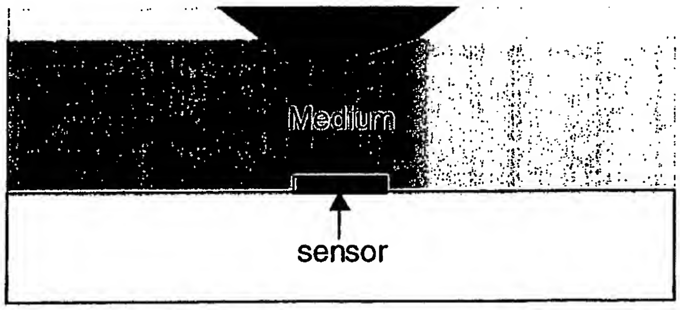
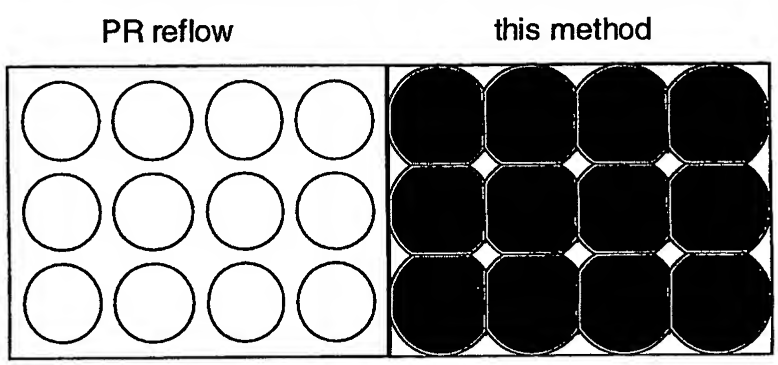
Inventor Signature	[redacted] Date	Witness initials (include date if witnessed on date different from above)



this method also demonstrate advantage over photo resist reflow technology on fill factor. As is shown in the following figure, by using this method, the lens could be made as big as filling the whole area, fill factor reaching 100% without causing other problems.



The method described here also applys to the lens that is not a round or square shape. For example, if the photosensitive device is a rectanglar shape, the dry etch opening on hard mask will be made in rectanglar shape accordingly so that the light will be focused on a rectanglar spot. If the photosensitive device is a square or round shape but the lens needs to be a rectanglar or other shape, then by opening the mask in a round shape hole, the finished lens will focus light in a single round shape spot while the shape of lens could be any shape as designed.

Inventor Signature	Date [redacted]	
Inventor Signature	Date [redacted]	T. Li Witness Initials (include date if witnessed on date different from above)
Inventor Signature	Date [redacted]	Witness initials (include date if witnessed on date different from above)

SHARP Laboratories of A rica, Inc.
5750 NW Pacific Rim Boulevard
Camas, Washington 98607

SLA Docket No. 0837

Q14. International prior art search report (Shortcut to MicroPatent).

Search Terms	

Reference:	
Summary:	
Distinguishing Remarks:	

Reference:	
Summary:	
Distinguishing Remarks:	

Reference:	
Summary:	
Distinguishing Remarks:	

Reference:	
Summary:	
Distinguishing Remarks:	

Reference:	
Summary:	
Distinguishing Remarks:	

Reference:	
Summary:	
Distinguishing Remarks:	

Once all related prior art references are identified and distinguished from the invention in this disclosure form, submit the complete disclosure form to your supervisor for his/her approval followed by submission to a patent attorney for their review **or** submit to a patent attorney first for approval of the prior art search followed by submission to your supervisor for their approval. Both signatures are now required before committee review.

11:25 AM [redacted] **Invention Disclosure** microlens.doc

Inventor Signature	[redacted] Date	
Inventor Signature	[redacted] Date	T.L. Witness initials (include date if witnessed on date different from above)
Inventor Signature	[redacted] Date	Witness initials (include date if witnessed on date different from above)

5750 NW Pacific Rim Boulevard
Camas, Washington 98607

SLA Docket No. 0837

Patent Department Approval:

Attorney's Signature: ______________________

Date: ______________________

If your disclosure is to be reviewed by the Patent Committee (Departments 1-4), you MUST also complete a Patent Evaluation Form. Staple the Disclosure Evaluation form to the front of your disclosure before submitting the disclosure to the Patent Department.

Inventor Signature	Date [redacted]	
Inventor Signature	Date [redacted]	T. Li Witness Initials (include date if witnessed on date different from above)
Inventor Signature	Date [redacted]	Witness Initials (include date if witnessed on date different from above)

Sharp Labs of America

To: Yoshi Ono
From: Wei Gao
cc: Group Files
Date: [redacted]
Subject: Monthly Report fo[redacted]

Microlens processing

With the new research theme change in this half, our effort is re-directed to the area of developing microlens shaping methods for micro-sensor integration technology. Based on the requirements from Sharp Japan, new proprietary methods are needed for microlens shaping. We have developed several lens shaping methods for this purpose.

Method 1.

This invention provides a method to fabricate an array of micro-lenses. In most prior art cases, the shape of the lens is made to protrude above the surface of the top plane to form the convex lens shapes. In this case, the convex lens is shaped into the plane with a novel etch technique. Although by doing this the thickness of the lens is increased for the same focal length, but the current device structure can accommodate this increase, and the simplicity of this method benefit much more. The mold for the lens is formed by one dry etch step and one wet etch step. The lens with high refractive index (***n***) is formed in the mold. The shape of the mold in this invention is controlled by the mask material, the underlying film that will generate the shape of the mold, the etch selectivity, and the duration of the etch. The process details could be calculated from the dimension of the desired lens and the targeted focal length. The collection efficiency could be maximized by increasing the fill factor value to as high as 100%. For the photosensitive device or lens array that is not in a square shape, this method could focus the light to a single round spot or a different shape of spot as required in the design. This method could not only be used on photosensitive devices, it could also be used on liquid crystal display panels.

Method 2 see SLA Disclosure by J.F. Conley, Jr., W. Gao, and Y. Ono
Method 3 see SLA Disclosure by J.F. Conley, Jr., W. Gao, and Y. Ono

The following section describes the key part of lens shaping from method 1, for other detailed description, see SLA Disclosure: "A method of making microlens arrays for photosensitive devices, and LCD displays," W. Gao, Y. Ono, and J.F. Conley, Jr., disclose[redacted]

This method forms a concave mold in low refractive index medium material so that the high ***n*** lens material could be filled in to form a convex lens to focus the light onto the photo sensisitive devices. Basically, after depositing low-***n*** medium layer ***b*** and high-***n***

hard mask layer ***a*** with thickness of ***t***, an opening with diameter of ***r*** is dry etched as is shown in the following figure. We used round shape opening in this example, it could be other shapes.

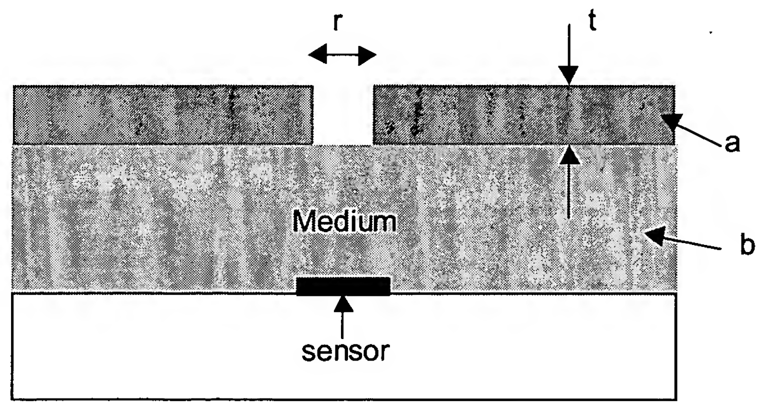


Figure 1

The next step is the wet etch. The etchant is chosen so that it etches both the hard mask ***a*** and the medium material ***b*** with a ratio of ***s*** in favour to the hard mask, i.e. the hard mask ***a*** is etched ***s*** times as fast as the medium material ***b***. The hard mask layer is consumed over time both vertically and laterally. This makes the opening bigger with time so as to form a cone shape mold. The etchant could be any state-of-the-art chemicals as far as it satisfies the selectivity requirement by this method.

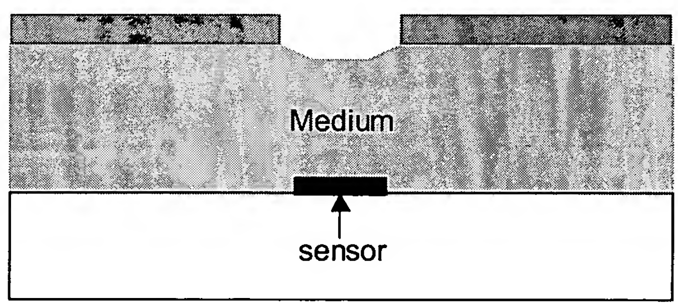


Figure 2

When the hard mask is consumed in its entirety, the etch could be stopped. The thickness of the deposited hard mask layer ***a*** is calculated so that by the end of wet etch, the mold will have the correct dimensions for the microlens. It can be formulated as the following:

lens diameter **D** = 2 x hardmask thickness ***t*** + diameter of dry etch opening ***r***
thickness of the lens **d** = hard mask thickness ***t*** / etch selectivity ***s***

Based on the nature of wet etches, the mold will have rounded corners which is likely to be better for light transmission.

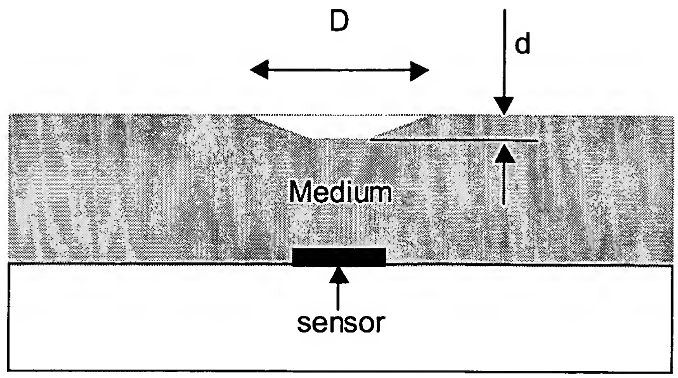


Figure 3

When the mold is formed, the lens material ***c*** with high refrective index value is filled in to the mold. The method of filling could be any state-of-the-art method, e.g. spin-on deposition, or glass deposition with reflow, sputter deposition with CMP, etc.

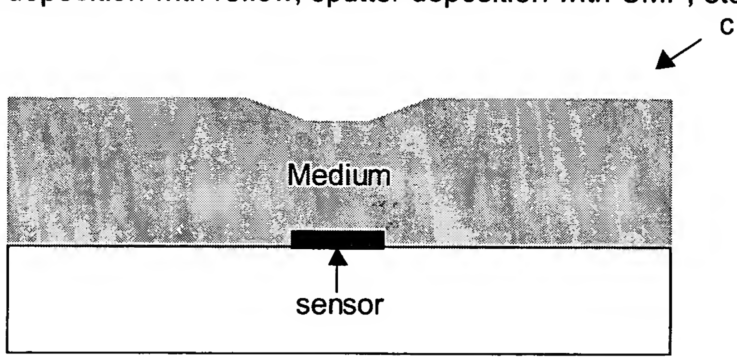


Figure 4

The lens could be used as is, or could be formed by one extra etching

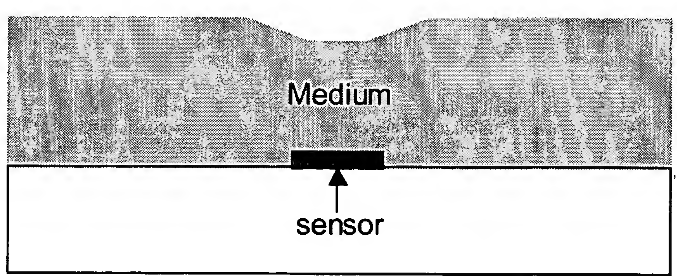


Figure 5

lens could also be formed by etch back or CMP.

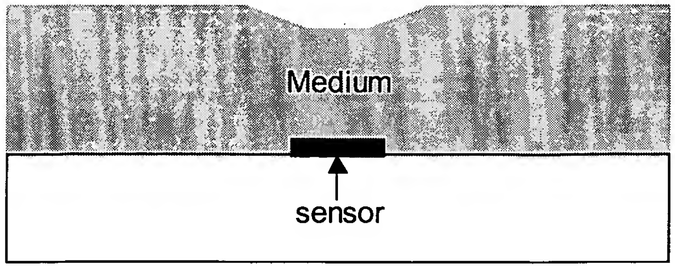


Figure 6

The key point for this method is to find the two materials with selectivity required by the etchant. Also the medium material has to be low-***n*** material. To demonstrate the lens shaping method, we used thermal oxide as medium layer and CVD TEOS SiO_2 as hard mask layer. The etch rate in 10:1 BOE is about 1:3, satisfy the lens shaping requirement, although the high temperature process for thermal SiO_2 is not suitable for the process integration.

Figure 7 shows that the shape of the mold is better than the shaped predicted in previous figures due mainly to the nature of wet etch. Left figure showed an array of lens molds and right one shows the profile of a single lens mold. It is estimated that the diameter of the lens is about 2.2μm and thickness of the lens is around 0.32μm. The focal length is around 5μm based on our simulation in which the refractive index of the top layer, lens and medium material is 1.0, 2.0, and 1.46 respectively. For this lens shaping method, the final shape is closely related to the size of the dry etch opening ***r***. it is easy to see that the lens on the left figure gives shorter focal lengthes mainly due to the narrower openings, in this case 0.6μm.

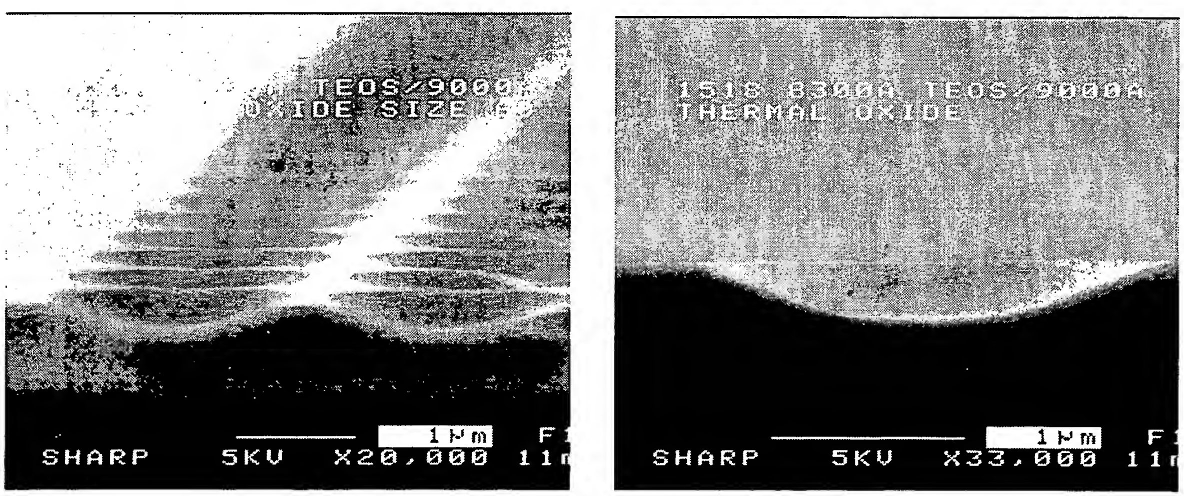


Figure 7. SEM pictures of microlens shaping method.

Sputtered ZnO study on Edwards

As part of the UV LED project, the effort is made on ZnO deposition method. Our first attempt is to use Edwards to deposit ZnO by reactive sputtering. For this purpose, a Zn target is installed and initial deposition experiment is carried out.

In order to obtain ZnO film, two approaches are used. One is to deposit Zn film and oxidizes it into ZnO. The other is to do reactive sputtering at elevated temperature to obtain ZnO directly. The Zn film is easily obtained after several tries while reactive sputtering at around 200°C is hampered by instrumental problems and is delayed. This month we report Zn oxidation experiment results first. The second approach will be carried out next month.

In the Zn oxidation experiment, around 60nm Zn film is sputter deposited in Edwards, and the film is annealed in Intex at 200°C and 300°C for 30min in clean dry air (CDA). After 200°C anneal, the film shows slight color change and significant optical property changes from spectroscopic ellipsometry measurement. However, XRD measurement does not show significant increase of ZnO composition. After 300°C anneal, the shinny surface changed to foggy surface and the following SEM figure shows the details of the film morphology change. In as-deposited Zn film, the grain size is around 100nm. After 300°C anneal, part of the film is oxidized. Due to the big lattice constant change, (>20%), the ZnO forms flakes and sticks up with Zn grain underneath remain visible.

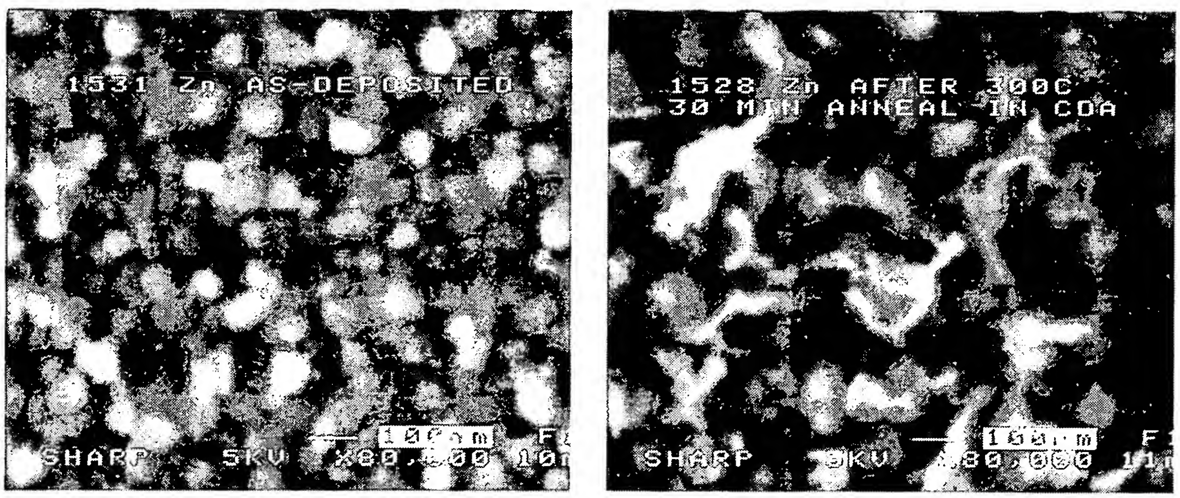


Figure 8, SEM images of Zn and ZnO films. ZnO film is formed by annealing Zn film in CDA at 300°C for 30min.

The following XRD phase scans show the changes before and after 200° and 300°C anneals. As-deposited Zn film shows all the major peaks, after 200°C anneal, the film is still dominantly Zn with ZnO (100) and (002) visible and Zn (002) peak reduced in height. After 300°C anneal, the ZnO peaks are significantly increased and become dominant while Zn peaks are significantly reduced. Based on SEM and XRD results, we

believe that since the ZnO could be formed at 300°C anneal, it should also be possible to deposit ZnO film in our Edwards sputter system by raising the temperature to somewhere close to 300°C. This way, the film quality could be preserved.

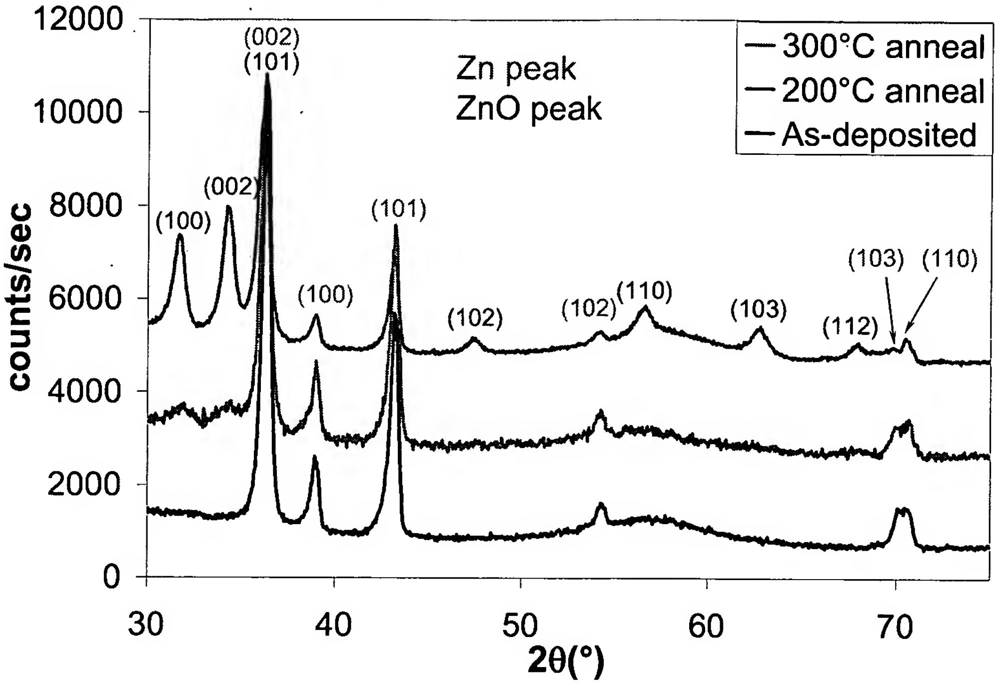


Figure 9. XRD scans for as-deposited Zn and after 200 and 300C 30min anneal in CDA.